REMARKS

At the outset, the Applicants wish to thank Primary Patent Examiner Anita Alanko and Patent Examiner Matthew Song for the many courtesies extended to the undersigned attorney during the Personal Interview on April 20, 2004 at the U.S.P.T.O. The substance of this Personal Interview is set forth on the Examiner Interview Summary and in this Amendment.

The Patent Examiner has repeated the Requirement for Restriction and has stated that non-elected claims 5-13 must be canceled when responding to the present Final Office Action.. For this reason, claims 5 to 13 have been cancelled without prejudice.

The Patent Examiner has formally rejected claims 1-4 under 35 U.S.C. §112, first paragraph, because the present Specification does not use the phrase "single type magnetic field". Therefore the Patent Examiner has indicated that the Specification does not provide support for this terminology in claim 1.

The Patent Examiner has formally rejected claims 1-4 under 35 U.S.C. §112, second paragraph, for being indefinite. The Patent Examiner has stated that the word "type" in the terminology "single type magnetic field" is in indefinite. Also the Patent Examiner has stated that the distinction between single type and double type of magnetic field is unclear.

For those reasons, the objected to terminology that "the traveling magnetic field is the single type of magnetic field which is applied to the melt" has now been cancelled. This objected to language has been replaced by the terminology that "except for said traveling magnetic field no further magnetic field being applied to the melt."

Support for this amendment to claim 1 and to claim 14 can be found in the present Specification on pages 11 and 12, in Examples 1 and 2 and in Fig. 1 to which the Examples are referring.

For these reasons, the present invention, and all the claims, are firmly believed to be in complete compliance with all the requirements of 35 U.S.C. 112. Withdrawal of this ground of rejection is respectfully requested.

New independent claims 15 and 16 are now being added. New independent claim 15 is based upon independent claim 1, except that new claim 15 recites in the preamble "consisting of the steps of" while claim 1 recites "comprising" in the preamble. New claim 15 recites in the last step that the traveling magnetic field is "to produce attenuation of low frequency temperature fluctuations". Support for this is found in the present Specification on page 11 in the top paragraph.

Newly added independent claim 16 is based upon independent claim 14, except that new claim 16 recites in the preamble "consisting of the steps of" while claim 14 recites "comprising"

in the preamble. New claim 16 recites in the "exposing" step that the traveling magnetic field is "to produce attenuation of low frequency temperature fluctuations". Support for this is discussed above regarding claim 15.

Because each of claims 15 and 16 recite "consisting of the steps of", each claim is so limited as to exclude any further magnetic field being applied to the melt, except for the traveling magnetic field.

The Patent Examiner has rejected claims 1-4 and 14 under 35 U.S.C. §103(a) a being unpatentable over *Tamatsuka et al* in view of *Luter et al* along with *Szekely et al* and *Lari et al* or *Morishita et al.*

The present invention is directed to a process for producing a silicon single crystal, comprising

pulling a silicon single crystal from a silicon melt which is contained in a crucible having a crucible wall and having a crucible diameter of at least 450 mm,

placing a heat shield above said crucible; and said silicon crystal being pulled with a diameter of at least 200 mm; and

exposing the silicon melt to an influence of a traveling magnetic field which exerts a substantially vertically oriented force on the melt in a region of the crucible wall, except for said traveling magnetic field no further magnetic field being applied to the melt.

The *Luter U.S. Patent No. 6,053,974* from column 2 line 53 to

column 3 line 3 disclosure apparatus which is a heat shield for use in a crystal puller around a monocrystalline ingot grown out of a crucible in the crystal puller filled with molten semiconductor source material. The heat shield comprises a reflector having a central opening sized and shaped for surrounding the ingot as the ingot is grown to reduce heat transfer from the crucible. The reflector is adapted to be supported in the crystal puller between the molten material and a camera aimed toward at least three separate points on a meniscus formed between the ingot and an upper surface of the molten material. The reflector has at least three passages extending through the reflector. Each of the passages is located along an imaginary line extending between the camera and one of the points on the meniscus. This permits the camera to view the points so the positions of the points can be determined by the camera for calculating the diameter of the ingot while minimizing heat loss through the passages.

Thus *Luter* fails to teach or to suggest a traveling magnetic field, as claimed.

The *Tamatsuka US. Patent No. 6,139,625* in column 6 in lines 11 to 35 discloses rapid heating rapid cooling apparatus in FIG. 3 which is a schematic view of a rapid heating/rapid cooling apparatus.

A heat-treatment furnace 10 shown in FIG. 3 includes a bell

jar 1 which is formed from, for example, silicon carbide or quarts and in which a wafer is heat-treated. Heaters 2 and 2' surround the bell jar 1 so as to heat the bell jar 1. The heater is separated along a vertical direction. Also, power supplied to each heater can be controlled independently. The heating method is not limited thereto, but so-called radiation heating and induction heating may also be applicable. A housing 3 as a heat shield is provided around the heaters 2 and 2'.

A water-cooled chamber 4 and a base plate 5 are arranged at the lower portion of a furnace so as to isolate the interior of the bell jar 1 from the atmosphere. A wafer 8 is held on a stage 7, which is attached to the top end of a support shaft 6, which, is turn, is moved vertically be means of a motor 9. In order to load a wafer into or unload from the furnace along a horizontal direction, the water-cooled chamber 4 has an unillustrated wafer port which is opened and closed by means of a gate valve. A gas inlet and a gas outlet are provided in the base plate 5 so that the gas atmosphere within the furnace can be adjusted.

Thus *Tamatsuka* fails to teach or to suggest a traveling magnetic field, as claimed.

The *Lari U.S. Patent No. 4,905,756* in column 3 in lines 3 to 7 discloses an electromagnetically cast steel sheet with a minimum of electromagnetic heating of the molten and solid steel and to provide a casting system with the molten metal in stable

mechanical equilibrium within the caster.

Lari in column 3 in lines 30 to 45 discloses an apparatus and method that combine a levitation magnet that produces low frequency magnetic field traveling waves with a stabilization magnet that produces a high frequency magnetic field to retain a metal in liquid form with a smooth vertical boundary. As particularly adapted to the casting of solid metal sheets, a metal in liquid form can be continuously fed into one end of the confinement region produced by the levitation and stabilization magnets and removed in solid form from the other end of the confinement region. An additional magnet may be included for support at the edges of the confinement region where eddy currents loop.

Lari in column 4 in lines 38 to 51 discloses two types of magnetic fields to act as a "magnetic pipe" in a casting process. The first magnetic field is a high frequency magnetic field parallel to the molten steel surface producing eddy currents in the surface of the steel which create inwardly directed forces on the surface.

This high frequency magnetic field confines the liquid metal in the same way as an ordinary solid pipe, hence the term "magnetic pipe". A second magnetic field, this one being a low frequency magnetic field perpendicular to the steel surface and traveling in a direction parallel to the surface creates body

forces throughout the steel. These forces act in the direction of the traveling magnetic field and offset the forces of gravity.

Thus *Lari* is nonanalogous prior art which relates to the casting of molten steel and not to producing a silicon single crystal.

The *Crowley U.S. Patent No. 4,808,079* in column 1 in lines 5 to 6 discloses a magnetic pump for pumping ferrofluids.

Crowley in column 2 in lines 27 to 32 discloses that the magnetic pump has at least two coils which are electrically connected to a multi-phase power source. The connection being such as to produce a traveling magnetic field. In close proximity to the coils is a tube for transporting the ferrofluid.

Thus *Crowley* is nonanalogous prior art which relates to a ferrofluid, and not to producing a silicon single crystal.

Morishita discloses a traveling magnetic field used for etching. This is nonanalogous prior art.

The *Ou Yang U.S. Patent No. 6,636,037* in column 1 in lines 8 to 12 discloses non-destructive magnetic probe testing and more particularly to an eddy-current probe and methods for using it for non-destructive testing of metallic objects, for example plates, and in particular, for example, aluminum aircraft skin.

Thus *Ou Yang* is nonanalogous prior art which does not relate to producing a silicon single crystal.

The *Szekely U.S. Patent No. 5,196,085* in column 3 in lines

31 to 43 discloses that in FIG. 2, a Czochralski crystal growth system 30 is shown wherein a stationary external magnetic field, B_o whose axial upward or downward direction is indicated by arrow 32 is applied selectively at the growing crystal surface vicinity 35 in combination with a moving magnetic field provided by induction coils 36 which also act as heaters. The moving magnetic field serves to stir melt 38 contained within crucible 40 characterized by radius, R_c 42, while applied external stationary axial magnetic field, B_o damps disturbances in crystal surface vicinity 35 as growing crystal 44 characterized by radius, R_x 46, is withdrawn from melt 38.

Thus *Szekely* fails to teach or to suggest a traveling magnetic field, as the only magnetic field, as claimed.

It is respectfully pointed out that *Szekely et al U.S. Patent No. 5,196,085* unambiguously teaches the applying to the melt a traveling magnetic field <u>as well as</u> an axial magnetic field (See *Szekely*, col. 2, lines 17-25). In contrast thereto, the claimed invention is a method, wherein a traveling magnetic field but <u>no</u> other magnetic field is applied to the melt. Therefore, claim 1 included the wording in the claim that the traveling magnetic field is the single type of magnetic field which is used in the present invention. However, this amendment caused some objection so that this language has now been cancelled.

The axial magnetic field which is not a part of the present invention ensures a laminar melt flow and quiescent conditions in the vicinity of the melt-crystal interface (See *Szekely*, col. 2, lines 17-33). *Szekely et al* teach that these conditions are necessary selectively at the melt-crystal interface to suppress flow instabilities and oscillations, which are generated by the stirring effect of the TMF (traveling magnetic field) in the bulk melt. However, quiescent conditions in the vicinity of the melt-crystal interface are conditions where temperature fluctuations are not likely to be removed as the melt flow is attenuated by the axial magnetic field.

According to the present invention, it is essential to consider that flow instabilities do not impact the generation of dislocations and therefore yield losses, but temperature fluctuations are responsible for that. Additionally, temperature fluctuations are not generally responsible, but only the low frequency temperature fluctuations and not the high frequency temperature fluctuations. The suppression of low frequency temperature fluctuations is achieved by <u>only</u> using a TMF, which generates a turbulent flow and increasing high frequency fluctuations of the melt velocity.

Therefore, the axial magnetic field which is taught by *Szekely et al* counteracts the effect of the traveling magnetic field. As *Szekely et al* teach the use of a traveling magnetic

field in combination with an axial magnetic field, this reference is not suitable to suggest the present invention which claims the use of a traveling magnetic field alone.

Thus the present invention provides a process for producing a silicon single crystal, and includes the step of exposing the silicon melt to an influence of a traveling magnetic field which exerts a substantially vertically oriented force on the melt in a region of the crucible wall, except for said traveling magnetic field no further magnetic field being applied to the melt. (Claims 1 and 14).

Because new claims 15 and 16 recite "consisting of", these claims exclude the axial magnetic field of *Szekely.*

By application of a TMF a stirring of the bulk melt can be achieved as taught by *Szekely,* too. As described in *Szekely* the melt flow in the bulk can be controlled, and especially a vertical flow is achieved in the vicinity of the crucible wall. Additionally there is a stirring at the melt surface with non laminar conditions. As commonly taught flow instabilities and oscillations at the melt-crystal interface vicinity generate dislocations and therefore low yields of dislocation free silicon single crystals. To insure laminar flow and quiescent conditions in the vicinity of the melt-crystal interface the reference teaches the necessity of using selectively an additional magnetic field (axial magnetic field), which suppress the non laminar flow

generated by TMF.

The present invention is based upon the fact that the TMF should not be used in combination with an axial magnetic field. It was additionally found, that the flow instabilities *Szekely et al* are referring to do not generate dislocations, but that the low frequency temperature fluctuations are responsible for dislocations. Additionally, it is pointed out, that high frequency temperature fluctuations are <u>NOT</u> responsible for generation of the dislocations, but only the <u>low</u> frequency temperature fluctuations. Further it was found, that it is possible by using a TMF, which generates a turbulent flow at the crystal melt interface, to suppress these low frequency temperature fluctuations. Hence, high yields of dislocation free single crystals can be obtained by only using TMF. In summary the TMF prevents generation of dislocations by only suppressing the low frequency temperature oscillations without suppressing the turbulent melt flow.

Hence *Szekely* fails to teach or to suggest that a TMF by itself produce attenuation of low frequency temperature fluctuations, as claimed.

For all these reasons, the present invention, and all the pending claims 1 to 4 and 14 to 16 are believed to be patentable over all the prior art of record under 35 U.S.C. 103. Withdrawal on this ground of rejection is respectfully requested.

Respectfully submitted,

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Enclosure:
1) Petition 3 Month Extension
2) Copy Petition 3 Month Extension
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Maria Guastella